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Pournelle, Phillip E.

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# A Transformational Framework for Design, Development, and Integration of Simulation Models

*LCDR Phillip E. Pournelle*  
*Deputy Chief of Naval Operations (OPNAV N81)*  
*2000 Navy Pentagon (Rm 4D453)*  
*Washington, DC 20350-5000*  
[Phillip.Pournelle@navy.mil](mailto:Phillip.Pournelle@navy.mil)

*Curtis Blais, Don Brutzman*  
*MOVES Institute*  
*Naval Postgraduate School*  
*700 Dyer Road Rm366*  
*Monterey, CA 93943*  
Email: [clblais@nps.edu](mailto:clblais@nps.edu), [brutzman@nps.edu](mailto:brutzman@nps.edu)

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**ABSTRACT:** *This paper addresses the current-day M&S market economy and argues that this economy is not able to meet the requirements of the new Analytical Agenda. Potential transformational solutions to meet this challenge are identified, calling for experimentation to discover a new framework for M&S development and composition. The resulting framework will become established in the community through community acceptance and supportive governmental policies.*

*A new class of Modeling and Simulation (M&S) capabilities is needed to support transformational studies and analyses. Software architectures for analytical M&S tools need to move away from monolithic, closed system designs to open M&S frameworks. New frameworks are needed to permit modular, loosely coupled components to be rapidly integrated to create agile analytical capabilities that can address the variety of missions conducted by today's warfighters. Tools built on these frameworks must be flexible, extensible, scalable to a variety of levels of combat, re-usable, executable in a desktop/laptop environment, convenient to use, able to exploit the best methods (functionality) available in various domains, and not bound to traditional approaches to combat modeling but able to model future concepts and to provide a framework for introducing wholly new concepts of warfare.*

*The Extensible Modeling and Simulation Framework (XMSF) is a composable set of standards, profiles, and recommended practices for Web-based M&S that has been emerging as a framework capable of supporting these activities. The Deputy Chief of Naval Operations (OPNAV N81) is sponsoring work to investigate an architectural framework for design, development, and integration of simulation models built on XMSF principles using two existing simulations: Naval Simulation System (NSS) and COMBAT<sup>XXI</sup>. The capabilities will be demonstrated by a Web-based simulation model composed using forces from NSS together with land-based units from COMBAT<sup>XXI</sup>. The framework provides the needed flexibility with its use of standards suggested by XMSF, especially the exclusive use of Extensible Markup Language (XML) for model interactions. This ensures that additional components can be added to the framework without requiring substantial internal modification. This framework illustrates the ability to achieve the requirements for M&S listed above.*

## 1. Introduction

Modeling and simulation (M&S) is an important tool used in planning, training, acquisition and other areas affecting fleet readiness. In the face of a geopolitical environment of uncertainty, the new Analytical Agenda requires M&S to be dramatically faster and more flexible. The M&S community currently cannot meet these commitments under its existing economic structure. Numerous M&S efforts in the past have been uncoordinated, stovepiped and slow in production. Unless the DoD transforms the way it conducts business, and the M&S community with it, DoD will never meet the overall objectives. The building of a “Market Place of Ideas” for M&S is required to meet the Analytical Agenda. New Web-enabled technologies can be employed to build this market place. The Chief of Naval Operation’s Assessment Division (OPNAV N81) is sponsoring an experiment to find the best framework to enable the Market Place of Ideas. Once a proper framework is ready for use, it should be evaluated for adoption across all M&S projects.

A new class of M&S capabilities is needed to support transformational studies and analyses. Software architectures for analytical M&S tools need to move away from monolithic, closed system designs to open M&S frameworks. New frameworks are needed to permit modular, loosely coupled components to be rapidly integrated to create agile analytical capabilities that can address the variety of missions conducted by today’s warfighters. Tools built on these frameworks must be flexible, extensible, scalable to a variety of levels of combat, re-usable, executable in a desktop/laptop environment, convenient to use, able to exploit the best methods (functionality) available in various domains, and not bound to traditional approaches to combat modeling but able to model future concepts and to provide a framework for introducing wholly new concepts of warfare. Such a transformation is occurring in the commercial world through service-oriented enterprise architectures, creating a new economy built around services, not systems. Corporations, and by extension DoD and the M&S community, must become agile in this new software economy or they will fall seriously behind the technological curve.

## 2. Background

### 2.1 The New Analytical Agenda

M&S is an analytical science that affects every activity in the fleet and will become ever more important in the swiftly developing defense strategy. M&S use by the services impacts every day operations around the world. Every war plan that has been executed has been evaluated

using M&S in one manner or another. Every platform, system, sensor and organization has been evaluated using M&S before it is fielded. The Chief of Naval Operations (CNO) has mandated that all acquisition programs will be evaluated in Campaign Analysis using M&S to present a consistent comparative methodology. The Assessment Division (N81) of the OPNAV Staff has been assigned to conduct Campaign Analysis for the CNO.

Various levels of application of M&S are shown in Figure 1. Campaign Analysis sits on the top of the M&S pyramid. It is supported entirely by the lower layers. It is dependent on the veracity of analytical content and data across the M&S pyramid. Because the CNO has mandated that all Navy funded acquisition programs must compete in a common Campaign Analysis, considerable attention and desire for participation in the modeling process has been focused on N81. Sea Power 21 warfare pillars [1], as well as programs from other services, have been rushing to N81’s doorstep. Each one of these programs is demanding their due attention and asking how they are being captured in the M&S world.

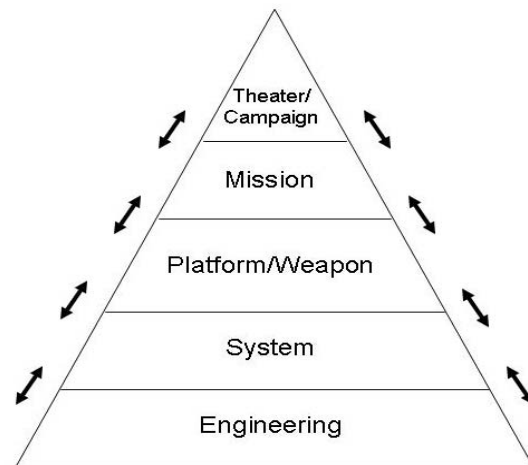


Figure 1. The Modeling and Simulation Pyramid: Dependability of results at each layer builds upon the layers below.

Unfortunately, it is often difficult if not impossible to capture the contribution of each warfare pillar’s systems, processes, protocols, etc. to answer these demands. In fact, the more transformational the program, the less effectively their impact on the battlefield can be demonstrated. Due to the slow production rate and lack of integration between models, the M&S community has not been able to evaluate these new concepts in a coordinated, swift and rigorous manner. An example of this is C4ISR and the “Fog of War” which have only recently been comprehensively captured in M&S. FORCEnet and Network Centric Warfare (NCW) are critical aspects of Sea Power 21 and require considerable effort to model and analyze. Modeling these C4ISR issues

is now the cutting edge of M&S after having been largely ignored for years. The problem is the incorporation of these ideas and others into our M&S models has been slow and cumbersome.

These factors, if they continue to prevail, will prevent the M&S community from meeting the challenges of the new Analytical Agenda, thereby impacting what systems and platforms the Navy will buy, plans the Navy will execute and the effectiveness of training to the fleet. Unless the M&S community is transformed, it will not be able to meet the needs of decision makers and the national strategy.

This paper addresses how we do business in M&S today and how it is not able to meet the requirements of the new Analytical Agenda. We will identify potential transformational solutions to meet the challenge and experiments to select the best framework, and then how to employ the new framework in a larger strategy by implementing it in new policies. In the end we need to find a way to create a "Market Place of Ideas" to create an efficient M&S economy.

## 2.2 A New Challenge

The challenge of the Operations Analysis (OA) community is defined in the new Analytical Agenda sent forward by the Office of the Secretary of Defense for Policy, Acquisition and Analysis (OSD(PA&E)) [2]. It lays out the DoD vision to use Capabilities Based Analysis to prioritize force structure and resource allocation. The origins of the Analytical Agenda sprang from the 2001 Quadrennial Defense Review [3] and the environment following the terrorist attacks on September 11<sup>th</sup>, 2001. The key term for the new threat environment is *risk*.

The Quadrennial Defense Review (QDR) required the services to complete the transition from a Cold War bipolar outlook to a multi-polar environment whose primary characteristic is uncertainty. Today this transition is slowly moving away from focusing predominantly on two major regional conflicts. The new Analytical Agenda demands that we move beyond the small number of traditional scenarios that we have been comfortable with and into a realm of considerable uncertainty and multiple shifting variables.

The most important aspect of the Analytical Agenda is the wide range of variables and situations to be evaluated. The most critical requirement of this is flexibility. The analytical process and its tools will have to be very flexible to meet the changing world we are living in to enable analysts to quantify risk.

The new Analytical Agenda demands exploration of the entire scenario space, not just the "most likely" areas M&S has focused on in the past. Numerous potential variables have to be considered such as the number of days of warning, Concept of Operations (CONOPS), Red chemical weapons use, Host Nation support, etc. Some of these variables are continuous, such as the time warning before hostilities begin; some are discrete, such as the CONOPS. In the past we have always modeled the "Most Likely" settings of such variables. The challenge we face today is that we live in an environment of risk where predicting the "Most Likely" scenario is difficult if not impossible. Recent events such as September 11<sup>th</sup> illustrate the catastrophic impact of not evaluating these variables from a risk perspective.

The challenge to the M&S community is to effectively evaluate all of these potential variables in a scenario across their entire range and produce analyses of the effectiveness of US and allied response in this multidimensional space.

However, the challenge does not stop within the individual scenario spaces. Due to the wide range of risk to US national interest around the world and limited warfighting resources, future force structures have to be evaluated not just within individual theaters but also across theaters. To properly meet the Analytical Agenda challenge, multiple force structures have to be evaluated across a wide range of scenarios. Within each of these scenarios the wide ranges of variables indicated above need to be considered. This is analytically challenging to say the least.

Given the requirements of the Analytical Agenda and the environment of risk that drives it, we need to see what the Analytical Agenda demands of the M&S community and how the M&S community is responding to those demands.

At the June 2003 MORS symposium [4] Dr. Paul Davis of RAND and Mr. Charles Swett of OSD (Policy) held a forum to discuss M&S requirements to meet the Analytical Agenda. They agreed we need a family of models that can talk to each other and give the analyst the ability to quickly conduct multi-resolution analysis [5]. Models must be able to quickly and flexibly capture and analyze new concepts and ideas. Additionally, we need to ensure the higher resolution/smaller scale models (represented at the lower levels of the M&S pyramid) supply data and findings to the next level of models to ensure new concepts and their impacts are properly addressed and abstracted at the lower resolution/larger scale models (represented at the higher levels on the M&S pyramid).

Figure 1 showed the M&S pyramid with multiple levels of resolution, each layer supporting the one above it. The analyst must be able to move up and down this pyramid to focus on areas of concern. Additionally the analyst needs to be able to build new branches on the M&S pyramid supporting concepts such as FORCEnet and NCW.

Figure 2 is a more detailed view of what the M&S pyramid is supposed to look like: multiple models, each built to do analysis at their level of resolution and each supporting the model above it. The models are the “bricks” in the overall structure, each requiring support from the levels below and supporting the level above. Like any structure, each brick’s value is not just in its own integrity but also in how it supports the integrity of the whole.

To meet the Analytical Agenda, the M&S community needs to produce modeling systems that are flexible, extensible, and scalable across the range of combat, reusable, desktop executable and convenient to use. These tools must enable the analyst to use the best methods in the field and quickly model future concepts to capture their contribution to the overall effort.

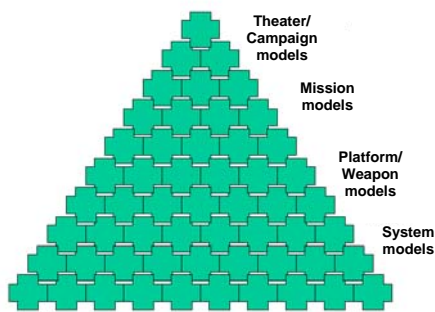


Figure 2. The M&S pyramid more accurately depicting the inter-dependencies and inter-relationships of the component capabilities and resolution layers.

What is needed is a fully integrated modeling pyramid. Unfortunately what we currently have, and may continue to have for the foreseeable future, is very disjointed. The current M&S pyramid lacks not only structure and organization for the bricks (models), it generally lacks any mortar (data transfer) connecting them. Few of the models are built to talk to each other in a constructive manner. Those models that do communicate often require significant manual work to enable data transfer from one model to another. This lack of mortar (data transfer) in this structure is very troubling. Due to the lack of a structure to transfer data, we can never be certain that the data being used at the Campaign Level is the most up to date or even accurate. Generally data developed at the engineering and system levels is not being fed to the

levels above them. The lack of a current and accurate (“warm”) database is very inefficient.

In addition to the lack of communication within the pyramid, the campaign models are generally focused on two major “most likely” scenarios of the past while the acquisition models are focused on their own narrow agenda and not designed to capture the multi-variability and risk assessment required in the Analytical Agenda. Thus in the current suite of M&S systems, the crucial overall effort is not extensible, scalable or flexible to meet decision makers’ quick turn needs. However, the most troubling aspect of the current business practices is the M&S economy. The best methods for analysis are scattered across different models and the analyst (customer) has no market power to efficiently draw them out. For an analyst to use the best methods in the field, he has to pay for multiple models. He also pays the infrastructure costs of those models, including other methods within the models that he is not interested in.

The analogy of a grocery store will illustrate the M&S customer’s predicament. When a person shops at a French market and asks for an apple, the proprietor goes in the back and brings out the apple he has selected. On the other hand, in an American supermarket, the shopper can select from all the apples the one he wants to buy. The M&S market place is even worse than the French market. Not only does the vendor select the apple for the customer, but the customer also has to buy a whole bag of groceries with it and has little say as to what groceries go into the bag (unfortunately, “requirements creep” occurs even in the most disciplined and well-controlled requirements analysis and development processes).

To make matters worse, the Navy as a customer has very diluted market power in the M&S community. Models can only be changed and updated through configuration boards, a committee system. The Configuration Board then makes recommendations through the developer (contractor, vendor, government) to make updates to the model. It should be apparent to anyone who has participated in these configuration board programs that the developer has the strongest voice in what will be updated. The authors are not disparaging the role or interests of the developer in this process, just reflecting the reality of the current M&S economy to illustrate where the government has largely abdicated its responsibility to promote the interests of the warfighter.

### 3. The Economy of M&S

#### 3.1 An Historical Perspective

To understand the situation the M&S community finds itself in, it is helpful to look at historic economies and

how they behaved. In the Mercantile Economy of the Middle Ages, construction of weapons, ships, etc. was based on individual efforts and configuration was based on the craftsmen involved. The only time that there were any common standards was when craftsmen were from the same guild or trained by the same Master Craftsman. The customer was very dependent on the craftsmen who built and designed a product for its future repair or modification.

In the Industrial Economy of the 19<sup>th</sup> and 20<sup>th</sup> centuries, construction was based on Assembly Lines and configuration was based on common standards. A part made in Boston worked on a ship constructed in Mississippi. The US Navy was able to dominate the seas in World War II and beyond due to the high volume and quality of ships and weapons systems that could be produced efficiently and effectively. The customer in an Industrial Economy was still dependent on industrialists, but less so as standardization prevented the industrialist from abusing (even monopolizing) the situation.

In today's Information Economy, construction of systems is based on fully netted development where systems can be tested in a virtual environment before any metal is bent. In an Information Economy, standards are self-synchronized through quickly identified and quickly utilized best practices. The customer in an Information Economy is in a dominant position because through the speed of information, he can quickly find the best product and price. The vendor knows this and quickly adapts his pricing schedule to compete. For producer and consumer alike, the watchword of the day is *agility*.

DoD's current objective is to move the military from an Industrial Economy to an Information Age economy with Information Age weapons systems [6]. The problem is the M&S community economy is currently Mercantile by nature. The M&S community is being asked to evaluate Information Age weapons systems using Mercantile age practices. The M&S community will not be able to meet the minimum requirements of the new Analytic Agenda until we can advance to at least an assembly line scale of production. In order to accomplish this goal, the M&S community will need to transform its economy.

The M&S community's current mercantile economy resulted from adaptation to the environment DoD created. A lack of active management, leadership and coordination within the services and across the acquisition and requirement organizations created individual fiefdoms. Each of the M&S organizations, particularly contractors, developed their business practices in response to that environment

The challenge to the M&S community, and to the analytic community in general, is to remain relevant in the new world context. To do so we must identify Transformational Solutions and determine how to best employ them, and this in turn requires that we examine other communities that have faced similar challenges and learn what we can from what they have done and how they succeeded.

### 3.2 Transformational Examples

Before Dan Golden took the helm at NASA, NASA was facing challenges to its relevancy, mission accomplishment and funding. Early in Dan Golden's tenure, he suffered losses of legacy systems he had inherited, including multi-billion dollar large satellite probes that failed. Due to the high cost of these systems, there were very few launches; a lot of eggs were in few baskets.

Dan Golden made a significant change in the mentality of the institution. Instead of the large multi-billion dollar probes, he shifted to small, nimble, single purpose probes. "Smaller, Cheaper, Faster" became his motto. NASA built smaller systems, each with a limited objective experiment. Later systems were built from previous successes. The most famous of those experiments was the Mars Rover. Based on the success of that program, there are two larger and more capable Mars Rovers exploring the Red Planet. These rovers were built based on the successes of the previous design. Another success that used this concept was the Delta Clipper-Experimental (DC-X) single stage reusable rocket demonstrator.

In recent years, the computer community has experienced one of the most extensive transformations ever. As computer networks were being developed from the ARPAnet to what we now call the Internet, the computer community experimented with standards to enable computers to talk to one another. Through the practice of experimentation, implementation and peer review the goal was accomplished. Today we are reaping the benefits of their work in the dawn of the Information Age. The fact that a MacIntosh computer can talk to an IBM machine and a SUN Sparc microsystem is testament to how low level protocols, strictly enforced and widely understood, can effectively enable a network to operate. The whole concept of Network Centrism can be traced back to this capability.

Another community has taken this concept a step further. The Open Source code community [7] has built, experimented with and conducted peer review of operating systems, utilities and applications. A number of the products created in this environment have been adopted by public and private organizations. The most

famous of these is the Linux Operating System. The key to this community's success has been the use of Open Source. By enabling all participants to view the code and see how it implements methodologies, improvements can be made, additional applications developed and evolutionary experiments conducted. The only requirement of authors of derivative code is to place their developments on the shelf beside the originals. Just as importantly, the approach prevents the sequestration of critical software elements behind "proprietary" barriers. DoD recently gave Open Source equal footing with proprietary software solutions: "Open-source software within the Defense Department is acceptable as long as it complies with departmental policies for commercial and government off-the-shelf software and meets certain security standards, according to a memo outlining the policy written last week by John P. Stenbit, assistant secretary of Defense and CIO at the department" [8]. Similarly, the Navy's Simulation Master Plan identifies the following strategies as steps to achieving "an integrated and nimble set of simulations that support big-picture independent assessments, cross-cutting analysis, and quick-turn tasking" [9]:

- Evolve methods to match simulation system capabilities to study requirements and create an open source repository of simulation software.
- Investigate the creation of an open source simulation code repository and a simulation XML tag set.

The common thread among these successful and transformational communities was identification of a core competency enabling innovation, followed by a series of experiments for iterative development, test, re-development based on the lessons learned and continued testing. They discovered and evolved best practices through experimentation.

It should be clear by now that the M&S community needs to be transformed. Like any true transformation, we need to change the way we do business and the way we spend money. We need to use new emerging technologies. More importantly we need to create an environment where the customer can obtain best practices and best methodology. We need a "Market Place of Ideas" for the customer (analyst) to go to and obtain the best tools to answer his questions.

### 3.3 A Paradigm Shift

Borrowing from the previous examples we need to identify the core M&S competency and how to enable it to transform the way we do business. The core competency in M&S is the ability to design mathematical models and representations for examining real-world situations and conditions. M&S uses computer programs to execute the bookkeeping necessary to solve complex

mathematical equations. Those equations are based on scientific methods we employ PhDs to develop. Too often we confuse the Model with the Method. Examples of methods include the Sonar Equation, the Radar Equation and Lanchester equations. The General Campaign Analysis Model (GCAM), Naval Simulation System (NSS), Tactical Warfare (TACWAR) and Integrated Theater Engagement Model (ITEM) are models that do the bookkeeping to employ such methods to produce outcomes.

Too often we attribute to the model what should be attributed to the method. To use an historic analogy we can look at ancient Israel. A criticism of ancient Hebrews was that the people had confused the Scribes as being the law. In reality the Scribes were people who could read and write and they were supposed to deliver the law to the people. The High Priests knew the law and developed it. Today leadership often mistakes the models and modelers as the priests, Models and modelers should be considered more as scribes. The high priests who are developing the law of M&S are our PhDs.

Once the *methods* are identified as the core competency of value, we are freed from the tyranny of the *models*. The goal is to make the M&S system implement the **best methods** that apply to the question at hand, not be restricted to *models* that may or may not deliver answers to our questions.

This then gives us the opportunity to develop a market place of ideas where the commodities of value are the scientific methods. As soon as we can buy methods and not have to buy into models we change the economy of the M&S world to the customer's advantage. The customer can select the best method to meet his needs and not have to pay for methods he doesn't need. This has two very important advantages. First, the customer can now more efficiently spend his resources to directly address the question he wants answered. Second, because the customer is no longer lashed to one or two specific models, he can more efficiently distribute the work in portions of the question to the best people in the field. A contractor would no longer be hired due to proficiency with a particular *model*; instead, the contractor would be hired for proficiency in a particular warfare area or concept. For example, the Navy might hire a contractor for his team's expertise in Air Warfare and another contractor team for expertise in Anti-Submarine Warfare (ASW). They have now been hired for their expertise in implementing a *method* not because they have the contract for a particular *model*. This efficient distribution of effort enables an analyst to obtain more data faster and more accurately with the same amount of resources. This will then enable him to run more excursions and perform sensitivity analyses, the place where the most insight is



gained! (Adam Smith described this efficiency of economy in his book *Wealth of Nations* [10].)

Now that the core competency (or key commodity) has been identified, *methods*, we need to transform the M&S environment to take advantage of this new commodity. The next step is to develop emerging technologies to enable use of the core competency to complete our transformation. We need a framework or a set of standards that ensure we can compose the best methods together in a way that makes them effectively communicate in a comprehensible manner. The central premise that we want a market place of ideas assumes the same central tenants of market economies; namely, that no one person or organization has the ultimate answer. No one model will solve all our M&S needs. By extension, no one person or organization will have the ultimate answer on what standards or framework will enable all the models to talk to each other or enable the best methods to be used together. Perhaps the same free market “invisible hand” that we wish to employ in our M&S market place of ideas can drive us to the best standards or framework to let the methods talk to each other.

The proposal here is to mandate that a standard be adapted in the near future, perhaps in two years. But in an effort to promote innovation, not suppress it, we should not specify what the standard will be. We should go further to say that the standard may not even exist yet. The preferred standard will emerge through open market experimentation.

### 3.4 Experimentation

To effect the M&S transformation, government is partnering with public organizations and private industry to sponsor experiments to attempt to find the best standard or framework enabling our market place of ideas, and opening the findings to public scrutiny, at least within the military M&S community. Once the M&S community knows that DoD is serious about mandating a standard but that the community can participate in the selection process, broad consensus will be achievable. This process will develop standards based more on attraction than on mandate-from-above. This will also allow the widest range of views to be heard before the selection is completed (not a precise moment of selection, but really a gradual widespread adoption of best practice and complementary standards).

While the perfect standard is not known now, there are key characteristics that are necessary to meet the military M&S needs and be effective. First, it must utilize low-level standards that are strictly enforced, not high-level standards with lots of waivers and exceptions. This facet

was critical to the development of the Internet. Second, it must support a market-oriented process that enables multiple users to participate. Third, the standard must be openly known and the source code that operates within it must be open for the entire M&S community, particularly the user, to review and use. Open source code serves two functions: it ensures the disparate modules are compatible (analytically) and that they can interact in an “operationally meaningful” way. By examining the source code the user can check to see if what he intends to do will work. Second, it opens up the whole M&S process to the same process we subject scientific works to, Peer Review. The user adopts the best methods available after the community has reviewed, tested, and nominally accepted them.

## 4. N81’s Experiment

### 4.1 Extensible Modeling and Simulation Framework (XMSF)

N81 is sponsoring an experiment with the Naval Postgraduate School’s Modeling, Virtual Environments and Simulation (MOVES) Institute and Operations Research Department to test if the emerging Extensible Modeling and Simulation Framework (XMSF) is a viable framework to meet the new M&S requirements.

The Extensible Modeling and Simulation Framework (XMSF) is a composable set of standards, profiles, and recommended practices for Web-based M&S seeking to exploit the rapid growth and widespread adoption of Web-based standards, tools, and technologies [11]. The initial effort involves an architectural framework for design, development, and integration of simulation models built on XMSF principles using two existing simulations: Naval Simulation System (NSS), an established constructive analytical model of the naval battlespace, and COMBAT<sup>XXI</sup>, an emerging Army/Marine Corps analytical model. Integration will occur through application of Simkit [12], an open discrete event simulation application program interface (API) used as the core simulation engine in COMBAT<sup>XXI</sup>. Technical details of this integration (via Web services) are described in a companion paper [13]. Initial capabilities will be demonstrated by various operational scenarios involving communication across these software components; e.g., using C4ISR elements from NSS together with land-based units represented in COMBAT<sup>XXI</sup>. The approach provides the needed flexibility with its use of standards suggested by XMSF, especially the exclusive use of XML for communications across components of the hybrid model. The approach enables additional components to be easily added to the framework without requiring substantial internal modification. Overall, the effort



illustrates the use of experimentation to explore techniques to meet the new M&S requirements.

The N81/NPS project is designed to evaluate the ability to apply XMSF concepts to provide a proper framework for M&S collaboration and build the “Market Place of Ideas.” To do this we intend to build from the ground up a simulation system as the core for other M&S modules to operate in. To prove the concept can work and produce meaningful data from known methods, we intend to fuse the best methods from three government-owned simulation programs. Simkit is an open source discrete event simulation engine written in Java and developed at the Naval Postgraduate School. Naval Simulation System (NSS) is a Naval Combat-focused object-oriented simulation model that emphasizes the units’ perception of the battlefield, communications and commanders’ perception and response. N81 has sponsored considerable work in expanding the ability of NSS to capture C4ISR issues, particularly in the realm of FORCEnet. COMBAT<sup>XXI</sup> is a ground combat oriented simulation model that emphasizes Army and USMC C4ISR issues. COMBAT<sup>XXI</sup> was developed using the Simkit engine. By fusing these systems together the resulting system will be a significant improvement in joint entity-level analytical modeling incorporating the best methods from Naval and ground combat models.

The test case we will examine in our experiment will be FORCEnet. The primary goal behind this entire transformational process is the ability to rapidly and effectively represent and evaluate transformational concepts. Command, Control, Communications, and Intelligence (C3I) capabilities in NCW are fundamental in future combat forces for all the services. Modeling NCW is the cutting edge of M&S today and a difficult challenge. If this new architecture can effectively represent and analyze NCW in a joint environment, we will have succeeded in proving that this architecture provides the ground for growth for transformational concepts. This will mean our “Market Place of Ideas” will have a large starting customer base.

After the initial XMSF experiment is completed, N81 plans to make the framework and M&S system with all supporting source code available to approved DoD agencies to begin to create a market place of users and developers. This process invites peer review of the framework, the M&S system and all files, as well as participation in evolutionary development of the capabilities. The intention is to continue building upon and improving the framework through ongoing development, test and experimentation. The goal is to enable others to build expansion modules that are compatible with the original framework. Borrowing from the NASA example, we will keep each module project

small and build onto the existing proven base. Specific projects can include finding and harvesting the best algorithmic methods from existing legacy models. This concept will enable us to build a Market Place of Ideas similar to the open source community.

As an impartial participant, a key responsibility for NPS will be to strictly enforce the standards in each of the modules constructed and to check the quality of the source code. In addition to the flexibility we will gain in the market place, the program will benefit from community Verification, Validation & Accreditation (VV&A) processes. Openness promotes transparency and honesty – all participants can review any submission, and only functional software is accepted by the community of developers and users. By posting the source code in an accessible location the project gains the advantage of peer review, both by academics and programmers.

As Figure 3 illustrates, XMSF’s use of the World Wide Web as a distributed modeling environment will enable a thin client user system to build a M&S solution importing the best methods in the field, without having to employ methods that are not important to the problem. Additionally, a collaborative Web environment enables multiple users to support each other’s efforts, providing each other the data necessary to complete complementary efforts. For example, a FORCEnet model could import data from a TENCAP system to use in a dispersed call for fire simulation while providing the background scenario required for the TENCAP study.

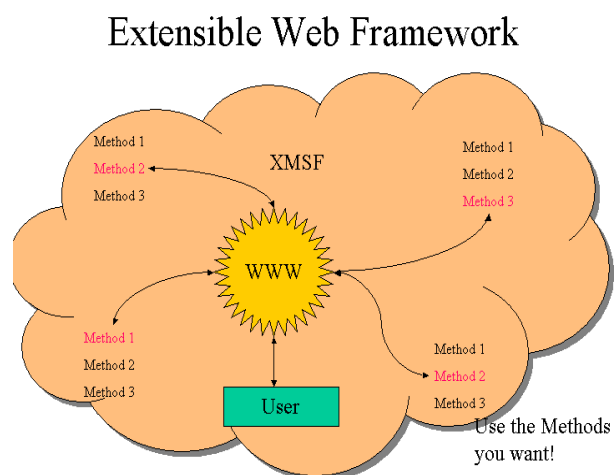


Figure 3. The new M&S paradigm exploiting the extensibility and scalability of Web technologies.

By using the principles of a Composable Modeling and Simulation Environment (CMSE) through the World Wide Web, we can enable collaboration between users who do not even know of each other’s existence. As the

data and methods developed and employed in this environment are exposed for M&S users to evaluate, new ideas and innovation will develop in the same way electronic business has rapidly expanded in the Internet environment.

#### 4.2 Next Step: Policy Change

Once a framework has been developed and a “Market Place of Ideas” is founded, the next phase will be to change policy to ensure it flourishes. To do this the DoD must change the way it spends money. We are advocating the Navy take the first step in transforming the economy of M&S to its advantage. Recently the Navy Modeling and Simulation Management Office (NAVMSMO) conducted a survey on where the Navy spends money related to M&S [14]. A conservative estimate is that it spends over \$370 Million dollars a year on M&S. Almost half of this is spent on acquisition programs for engineering models that are single purpose stovepipe systems. The remainder is spent in other realms, but again many are single purpose stovepiped models.

Upon selection of a framework, DoD should post it and all implementing M&S systems, with their source code, where all DoD agencies can obtain and review it. DoD should then embark on a strategy to develop new modules, carefully building new independent capabilities into the M&S system for the whole community to be able to review and use. DoD should borrow NASA’s strategy of smaller, cheaper, faster systems by keeping each module development project small. Strict enforcement must be maintained on all modules developed and each project should build upon previous work. This is a key enabling attribute of an open source code policy. The module development strategy should be used to harvest the best methods from legacy models, bringing best of breed into the market place of ideas.

Initially this transformation strategy and its framework will be based on attraction. But in the near future DoD must select a framework and ensure all M&S programs shift to it. The only way we can transform the M&S economy is to adopt community wide standards that everyone has access to and will use. To bring this about DoD must change the way it spends money on M&S.

DoD will need to conduct a complete review of all its M&S programs. We need to ensure all M&S projects are aligned to support the Analytical Agenda and contribute to a holistic M&S pyramid. Programs that cannot demonstrate ability to quickly contribute data and findings to the overall M&S effort should be realigned or cancelled.

Every M&S program should be required to identify themselves to the M&S management, define their position in the M&S pyramid and identify what model(s) in the pyramid they support (e.g., using metadata, possibly through the concepts of XMSF Profiles [15]). They should be able to demonstrate their ability to quickly support the other models, either through real time support, data tables or adjudication tables. These models must demonstrate their ability to provide “warm” databases. Finally, each M&S system must demonstrate their validity by opening themselves up to a peer review process by posting their source code where DoD agencies can examine and work with it.

Every Acquisition program should be required to report a Milestone ensuring the program has been tested using M&S aligned to the overall M&S effort and meeting the new M&S collaborative framework.

Most of the discussions in this article so far have dealt with analytical M&S models. Transformation of analytical M&S models is not sufficient. All M&S systems need to be transformed including Planning and Training programs, Acquisition programs, Fleet Experiments, etc. If a proper framework is developed and implemented each of these “faces” of the M&S pyramid will be mutually supportive of the whole structure, as indicated in Figure 4. Analytical models should be ready to provide Planning and Training models with the background and scenarios for effective training. In return these Planning and Training models should be providing human performance data to be incorporated in Analytical models. Fleet experiments should be able to draw upon analytical models to provide all of the notional actors and their interactions while collecting organizational performance data.

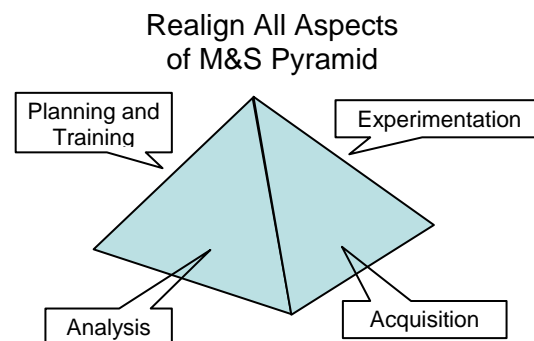


Figure 4. A realigned M&S pyramid integrating across levels and purposes.

One of the critical criticisms of NCW and Effects Based Operations is the lack of data to support their claims. They also lack models that effectively capture the

mechanics of how they operate. By building a proper framework, DoD can obtain and maintain required data in an effective manner and provide answers to these transformational concepts.

## 5. Summary

The Modeling and Simulation community is facing a serious crisis. Its reason for being is the new Analytical Agenda. However, the M&S economy prevents the community from meeting the demands of this agenda. If the economy of the M&S community is not changed, it will become irrelevant. DoD should embark on a plan to transform the manner we conduct business and find the best common framework that enables the analyst to use the best methods in the field. Once we find the framework we need to realign all M&S efforts to comply. Once we demonstrate the M&S community can deliver assembly line production levels of studies, new life will be instilled into the industry. As the word gets out that the M&S community can answer transformational questions in a timely manner, more questions will be asked of it.

The only way DoD can transform M&S to meet the Analytical Agenda is to change the way it spends money and conducts business. To meet the demands of senior leadership, DoD must create a new M&S collaborative framework enabling a “market place of ideas” while providing active leadership and management of people, resources and programs. The OPNAV staff is funding an experiment in XMSF technology to find the best M&S collaborative framework. Other DoD agencies should fund their own experiments to enable competition to discover the best one.

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## Author Biographies

**LCDR PHILLIP POURNELLE**, USN works on the Chief of Naval Operations staff in the Assessments Division Campaign Analysis team. He is a graduate of the Naval Postgraduate School Operations Analysis program. He is a Surface Warfare officer and has served on cruisers, destroyers and amphibious ships.

**CURTIS BLAIS** is a member of the Research Faculty in the Modeling, Virtual Environments, and Simulation (MOVES) Institute at the Naval Postgraduate School (NPS), Monterey, California. He is working a number of research efforts in application of Web-based technologies to military modeling and simulation, including the Extensible Modeling and Simulation Framework (XMSF), the Military Operations Other Than War (MOOTW) Flexible Asymmetric Simulation Technologies (FAST) Toolbox, Common Maneuver Networks (CMN), and the OPNAV N81 World-Class Modeling program. He received B.S. and M.S. degrees in Mathematics from the University of Notre Dame, and is currently a Ph.D. candidate in MOVES at NPS.

**DON BRUTZMAN** is Associate Professor in the Modeling, Virtual Environments, and Simulation (MOVES) Institute (<http://www.movesinstitute.org>) and Chair of the Undersea Warfare Academic Group. Dr. Brutzman is leading multiple efforts in the Web3D Consortium to produce next-generation Web3D specifications and tools, including the ISO-standard Extensible 3D (X3D) Graphics Specification. As MOVES Technical Director for Networked Virtual Environments and 3D Visual Simulation, he directs the construction and integration of internetworked physically based models for large-scale virtual environments through development of X3D and dynamic behavior protocols, including serving as Principal Investigator on the XMSF project. He received a B.S.E.E. in Electrical Engineering from the U.S. Naval Academy, and earned M.S. and Ph.D. degrees in Computer Science from the Naval Postgraduate School.